Assessment of Transoceanic NOBOB (no-ballast-on-board) Vessels and Low-Salinity Ballast Water as Vectors for Nonindigenous Species Introductions to the Great Lakes

A new $1.9M three-year research program involving collaboration between six institutions is being conducted by a U.S.-Canadian team of scientists. The program is led jointly by the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Lab (GLERL) and the University of Michigan's Cooperative Institute for Limnology and Ecosystems Research (CILER), both located in Ann Arbor, MI.

Goals and Objectives

The primary goals of this program are to provide the scientific knowledge needed to understand the risk of invasive species introductions posed by transoceanic NOBOB ("no-ballast-on-board") vessels operating in the Great Lakes, to provide a basis for identifying effective preventive measures and for developing policies and biological standards for ballast water treatment, and to experimentally determine the effectiveness of open-ocean ballast exchange with special attention to low-salinity or fresh water initial ballast. Specific tasks are to:

Task 1: characterize the biological communities (invertebrates, phytoplankton, and microorganisms) present in NOBOB tanks and evaluate the relationship between ship management practices, mud accumulation, and invasion risk.

Special focus on resting stages - the importance of invertebrate, phytoplankton, and microbial resting stages to invasion potential in the Great Lakes has never been determined.

Task 2: conduct experiments in ballast tanks of operating vessels to determine the potential for introduction of nonindigenous organisms when Great Lakes water is added to a NOBOB tank containing residual sediment and water, and later discharged.

Task 3: quantify (for the first time) the effectiveness of open-ocean exchange in decreasing the diversity and concentration of live nonindigenous species that enter the Great Lakes in exchanged ballast water, especially targeting fresh or low-salinity ballast water originating from Europe.

The side and bottom ballast tanks are visible (yellow-orange areas between large open hold space and the outside hull) in this section of a vessel being modified in dry dock (photo by P. Jenkins).

Background and Issues

A ship taking-on ballast water in a foreign port for purposes of trim and stability also takes-on the biota and sediment in that water. When a ship with foreign ballast water enters the Great Lakes it carries foreign biota with it, unless measures have been taken to remove or kill the biota. The Nonindigenous Aquatic Nuisance Prevention and Control Act (1990, P.L. 101-636) requires that ships coming into the Great Lakes “in ballast” after having operated outside the U.S. Exclusive Economic Zone must exchange that ballast water at sea, conditions permitting, or use an alternate ballast water treatment approved by the U.S. Coast Guard. Presently, open ocean ballast water exchange is the only approved treatment. The purpose of requiring ballast water exchange is to reduce the risk of introducing invasive species to the Great Lakes via ballast water discharge. However, statistics reveal that over 75% of vessels entering the Great Lakes declare that they have no pumpable ballast water on board (NOBOB) and are not subject to ballast management regulations.

Studies have shown that the “empty” ballast tanks in NOBOB vessels often contain an unpumpable residual mixture of foreign sediment and water accumulated from previous ballasting operations. Only a few studies have examined the biological content in NOBOB tanks and have found that these tanks may contain thousands of live organisms, their resting stages (eggs and cysts), and microorganisms, including human pathogens.

In addition, when a NOBOB vessel unloads cargo in the Great Lakes, Great Lakes water is pumped aboard to maintain the stability of the vessel. Thus, Great Lakes water mixes with the residual ballast water (and organisms) already in the ballast tanks. Vessels often move between a succession of ports, unloading foreign cargo and loading domestic goods for export. As a result, ballast water is pumped on and off the ship several times during its stay in the Great Lakes, and foreign organisms or their resting stages can thus be discharged into the lakes during these ballasting operations.

Residual water and sediment in a ballast tank of a transoceanic NOBOB vessel operating in the Great Lakes (photo by P. Jenkins).

The effectiveness of open-ocean ballast water exchange in minimizing species introductions has not been well tested or evaluated. Most ships sampled during 1995 at the entrance to the Great Lakes carried an assortment of live marine, brackish and freshwater fauna, despite having fully exchanged ballast water on the open-ocean. A Canadian study determined that up to one-third of ships that declared mid-ocean exchange still contained live, freshwater-tolerant zooplankton. Another study found only a 48% difference in the densities of diatom and dinoflagellates between exchanged and un-exchanged ballast tanks. The euryhaline fishhook waterflea, *Cercopagis pengoi*, invaded Lake Ontario in 1998, well after implementation of open-ocean exchange. New introductions since the implementation of mandatory ballast exchange have raised questions about the effectiveness of ballast exchange in protecting the lakes. On the other hand, the new organisms could have entered from a NOBOB tank that was ballasted and discharged after entering the lakes.

A resting egg pouch (ephippium) and the juvenile Daphnid that just hatched from it. The Daphnid is still in the process of breaking out of its individual egg casing, which appears as a transparent oval-shaped frame around the animal. Collected from residual sediment of a NOBOB ballast tank in 2001 (photo by S. Bandoni and H. MacIsaac).

What are "Resting Stages?"

The life cycles of many aquatic plants, invertebrate animals, and microbes include the capability of producing resting stages (variously called cysts, ephippia, resting eggs, or spores according to taxon).

Resting stages are rarely produced under favorable environmental conditions, but under conditions that threaten the well-being of the organism, such as declining food resources, lower oxygen levels, loss of light (for photosynthetic plants), or extremes of temperature, resting stages can be produced very rapidly.

Resting stages are extremely resistant to conditions such as lack of oxygen, exposure to toxic chemicals, low and high temperatures, and even survive passage through the digestive systems of fish and waterfowl.

Resting stages may remain in sediment in a state of virtual suspended animation for decades or even centuries. Once exposed to the right combination of favorable environmental conditions, they can hatch or germinate to produce live organisms capable of reproducing.

Despite popular perception, there exist very few quantitative studies that have measured the preventive value of exchange. Those that have been documented were restricted to just a few vessel types and only assessed the effect of exchange for a small subset of entrained taxa. Furthermore, most of these previous studies were restricted to broad taxonomic groups of large planktonic organisms and ignored microorganisms and those taxa that form cysts.

A crucial consideration for the Great Lakes is the effectiveness of open-ocean ballast exchange when the original ballast is fresh or low-salinity water. The organisms and resting stages in fresh or low-salinity ballast water pose the greatest invasion risk to the Great Lakes. The freshwater regions of Europe and especially the coastal regions of the Baltic and Black Seas have been implicated as source regions for most ballast-related Great Lakes invaders found since 1985 (zebra mussel, quagga mussel, round goby, tubenose goby, amphipod *Echinogammarus ischnus*, the fishhook waterflea, *Cercopagis pengoi,* and the diatom, *Thalassiosira baltica*). Many of the aquatic organisms found in these regions (a) are euryhaline and can survive exposure to moderate salinity and (b) form resting stages that accumulate in bottom sediments, and are difficult to remove with exchange. Therefore, the effectiveness of exchanging freshwater from these regions for open-ocean saltwater is an important, largely unresolved question.

Live harpacticoid copepod found in the residual water of a NOBOB ballast tank in 2001 (photo by H. Limén and H. MacIsaac).

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Entering and exiting ballast tanks requires agility and flexibility as well as extensive safety preparations (photos by D. Reid).

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